Final Report for NASA AISRP Grant NAG9-10432

Project Title:
"Precision Mining" of Large Data Volumes for Rapid Identification of Planetary Resources

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Project period: 3/1/2000 – 8/31/2004
with a 7 months gap in funding 8/15/00 - 2/1/01
due to grant transfer from U Arizona to Rice U
and with a 1-year no-cost extension 9/1/03 - 8/31/04

Project URL: http://www.ece.rice.edu/∼erzsebet/HYPEREYE

Contents

1 Project Summary (from original proposal)

Data transmission severely limits the return of raw data from high-rate instruments on deep space missions. For example, a high-resolution imaging spectrometer at Mars could collect data more than 10^6 times faster than the best available downlink rate. There is a pressing need for rapid yet intelligent on-board analysis for selection of key data to return to Earth (along with generated knowledge). The highest priority observations, such as compositional mapping over hydrothermal vents, may require only a small fraction of the total data volume. We will apply state-of-the-art parallel computational technology, a hybrid neural network with a Self-Organizing component, for fast clustering and classification of planetary multispectral data. Our approach is powerful because: (1) the massively parallel algorithm can be readily implemented in hardware to process a high-volume data stream in (near) real time, and

(2) neural network clustering and classification is superior to conventional methods. This approach will enable space scientists to extract key information from high-rate imaging spectrometers or other instruments expected from NASA's flight missions. We will develop automated processes to evaluate and render cluster information, integrated with pre-processing and supervised classification, to be used for on-board analysis with limited human interaction as well as for the analysis of large data sets on the ground. We will build on existing and commercially available products as well as on our previous work, and test the resulting tools on Clementine and Mars Pathfinder multispectral data sets and AVIRIS hyperspectral image cubes. The product will be applicable to a wide range of planetary missions and will be made available to the scientific community. We plan to follow up with a separate project to implement the software into a high speed parallel hardware board specifically tailored for an instrument that is being planned at LPL for a Mars orbiter mission.

This project is a collaboration between computer science and space science investigators within LPL, University of Arizona.

2 Accomplishments

2.1 Completion of project tasks (neural algorithm and software development, and analysis of space and earth science data)

This project concluded in this project year. Efforts resulted in HYPEREYE, a three-faceted software system whose conceptual scheme is shown, as it was proposed originally, in Figure 1.

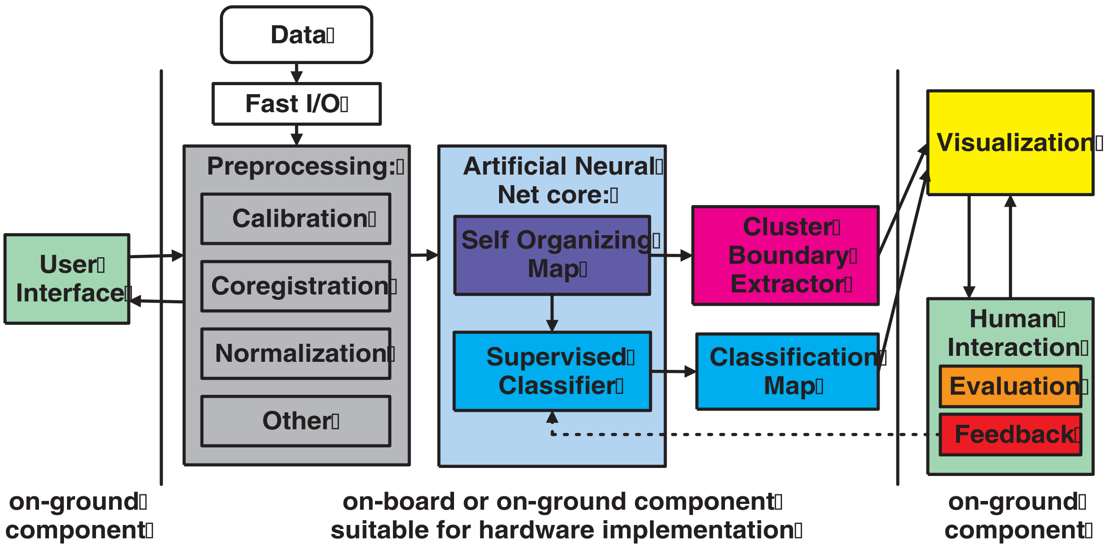

Figure 1: *HYPEREYE conceptual scheme. The color coding ties to functional modules of the software implementation of the system, details of which are shown in Figure 2.*

These components are now functional. We engineered a number of prototypes that the PI had at the beginning of the Award period, as well as developed entirely new, interactive functionalities, integrated and supported under a main GUI. The development of parallel algorithms (ANNs) is realized via software simulation. Hardware implementation of designated parallel components is planned for a separate (much more costly) project. A simplified overview of the software implementation of HYPEREYE is provided by the following chart in Figure 2.

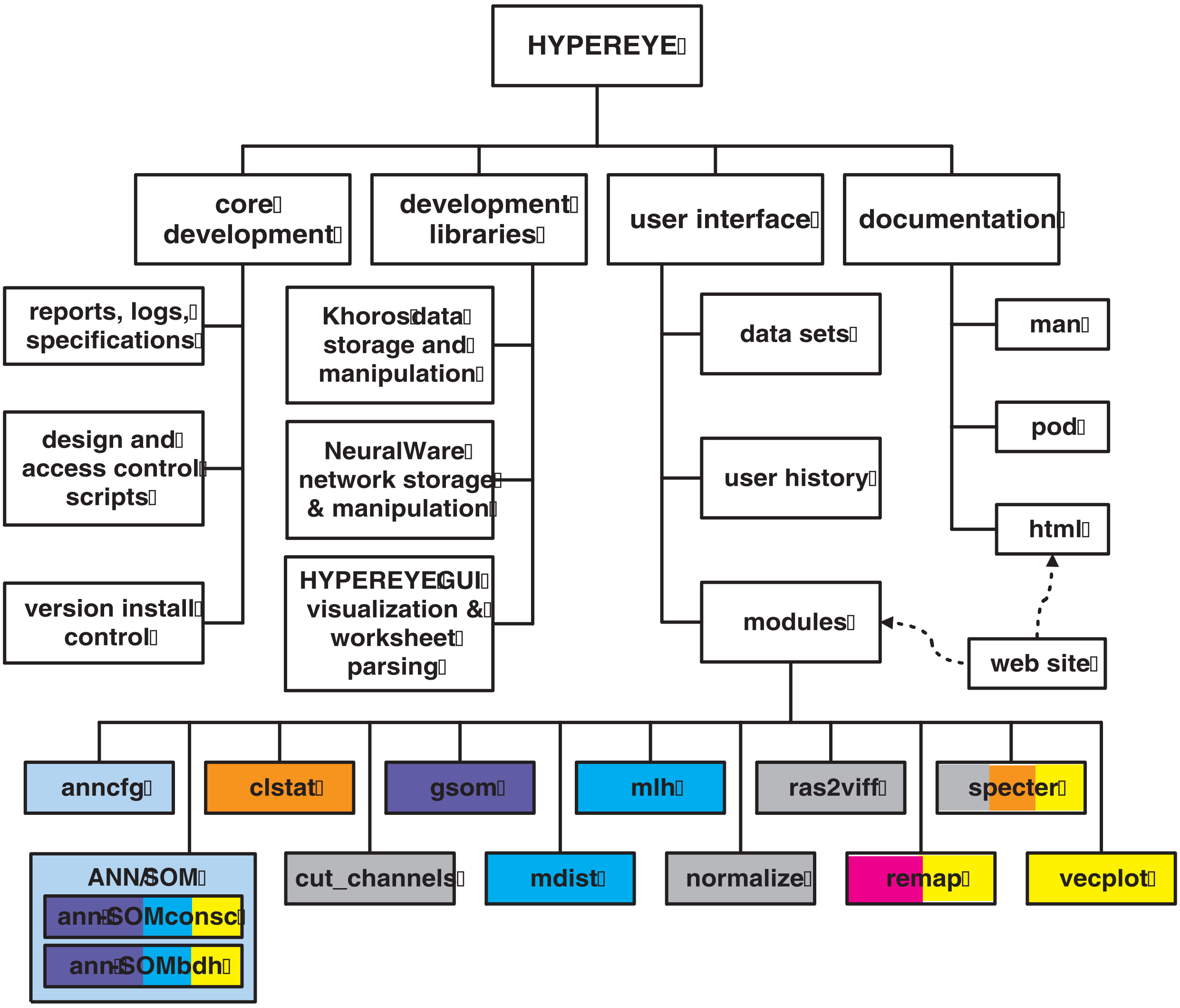

Figure 2: *Overview of HYPEREYE components. The color coding ties to conceptual blocks of the system, described in Figure 1, indicating the mapping of conceptual functionality to implementation by software modules. This chart shows the top level structure of HYPEREYE, with major functional components. Modules related to ANN/SOM algorithms are in the blue hues, dark blue for unsupervised (SOM) algorithms, turquoise for supervised classifications, and pale blue for other ANN related modules. Yellow shows visualization components, cluster boundary extractors are highlighted in hot pink, and orange labels evaluation of results such as class and cluster maps. Preprocessing capabilities are shown in grey. Two colors, green and red are missing compared to the conceptual chart. Green would stand for the main GUI of the overall system, and red for human control/feedback. The latter will be exercised through the main GUI upon the completion of a "next generation GIU" (see Task 1). Human control/feedback for individual modules is built into the modules' GUIs. As seen, several modules are coded by multiple colors, indicating more than one type of functionality from the concept blocks.*

This overview reflects the three-faceted nature of the HYPEREYE system: It is 1) a collection of data analysis algorithms for scientific users (the colored bottom layer and "documentation"); 2) a programming environment for algorithm development and research; and 3) a data organization and process (neural network) management facility for storing imagery and neural networks, and tracing analysis history.

Accomplishments for this Award period are listed according to the originally proposed Tasks.

Task 1: GUI and supporting modules accomplish the promises, and more, under this Task as partially seen from the HYPEREYE overview chart in Figure 2. File and version tracking, automated file name generation, history tracking all work within the individual modules.

HYPEREYE components are supported by libraries of commercially available high quality software packages, notably Khoros 2.2 (Rasure and Young, 1992, Khoral Research, 2000 -) and NeuralWare's NeuralWorks Professional II/Plus, Designer Pack and User Defined Neurodynamics packages (NeuralWare, 1993 - 2003) for more efficient code development and integration with image manipulation. The Khoros "polymorphic data structure" philosophy enables a new level of data handling. With the arrival of Philip Tracadas in February, 2003, software development was significantly envigorated. The system's artificial neural net core now executes up to seven times faster (on the same CPU) than before; user documentation is completely up-to-date, automatically generated and avilable both as man pages and web pages. Tracadas also developed efficient support for code development by students, through templates. As a result of developing her work in the HYPEREYE system, Jain, for example, was able to quickly implement the BDH algorithm (see Task 2) and apply it to demanding data sets.

The last 6 months of this project period was spent on pulling together the HYPEREYE modules under a main handler, the HYPEREYE GUI. This was done with forward planning for the "next generation GUI", for our next Award period (grant NNG05GA94G, 11/1/04 - 10/31/07). A worksheet description language was implemented using XML so that modules can describe their worksheets to the HYPEREYE GUI. The advantage of this design is two-fold: on the module side, new keywords are added in one place and are automatically understood by other (supervising) applications; on the GUI side, the keyword description information helps the GUI present to the user a guess at the eligible options for that keyword, and it enables error checks on the user's final entries.

Neural network algorithm design is a key facet of our research. The HYPEREYE application and library environment facilitates this development among students, staff, and faculty. Currently, many parts of the network analysis system have hooks for standard C (or Fortran) functions which isolate the researcher from the mundane data handling and graphics presentation. To further refine this isolation, a dynamically loadable plug-in architecture (the network visualizer "vismod") was developed to enable researchers to rapidly develop visualization algorithms (like SOM weight distance (fence) metrics, cluster extraction, etc.). These algorithms can then be loaded into already compiled modules instantly without the overhead of maintaining separate execution versions of the modules. This plug-in architecture will also be extended to network learning algorithms and file-format readers under the "next generation GUI".

Additional capabilities that were created include a spectral-statistics plotting module "vecplot" which is both a stand-alone module and a plotting library that can be used by other parts of the system. Module error-message passing has been improved so that unique module codes and/or common error codes can be used by the HYPEREYE GUI. Database support for other platforms and/or other user locations was investigated in preparation for future extensions. We have begun creating tables that will be used by the HYPEREYE GUI and are being used by our website.

Task 2: Engineering, augmentation and refinement of ANN modules.

Dr. Thomas Villmann's GSOM algorithm (Bauer and Villmann, 1997; Villmann *et al.*, 1998) was fully adapted to our software design in two stages, and tested during his visits in 2002 and 2003. His Topographic Function for measuring topology violation in SOM mapping (Villmann *et al.*, 1997; Bauer *et al.*, 1997), was also adapted, however, it turned out too computation intensive. We will revisit this task when CPU speed makes it more economical, or if we achieve hardware implementation (which was not part of the plans for this project). Collaboration with Dr. Villmann led to the writing of a joint book chapter (Villmann and Merényi, 2001), and several journal and conference publications (Villman *et al.*, 2003; Villmann and Merényi, 2002; Merényi and Villmann, 2002; Villmann and Merényi, 2000)

In addition to what was planned, the SOM variant by Bauer, Der, and Herrmann (1996) was implemented in the system's neural core and investigated by graduate student Abha Jain to analyze the algorithm's capabilities to enhance the detectability of rare classes in the SOM lattice (see Jain and Merényi, 2004). This scheme (called BDH by us) provides a rigorous basis to apply an information theoretic approach to control the functional relationship between the *pdf* of the input data and the *pdf* of the SOM weights (the quantization prototype vectors) in the input space. A special case is a linear relation, which corresponds to the information theoretically optimal information transfer from input space to SOM. This type of mapping is realized by the Conscience algorithm (DeSieno, 1988), but the Conscience algorithm is heuristic, cannot be proven, and cannot realize any other functional relationship. Another interesting case is the functional relation involving a negative power, which causes rare events (classes) to be represented by an enlarged area in the SOM, therefore making the detection of the rare class easier. The theory, however, only supports very limited types of data (1-d, and 2-d with factorizing *pdf*). We started a line of study through numerical simulations, to chart the validity of the BDH for "forbidden" data, since those data would benefit most significantly. Along with Jain's studies, the preliminary findings were so encouraging (Merényi and Jain, 2004; Merényi, Jain and Farrand, 2004), and the impact on data mining potentially so significant, that we decided to pursue this direction of research more seriously. This topic constituted the majority of Jain's M.Sc. thesis. Dr. Villmann provided consultation on algorithmic details, and he served as an external member on Jain's thesis committee. Jain graduated in April, 2004.

Collaborator Fyfe visited once, and had fruitful exchanges with the PI, for both research and teaching. Fyfe and his group analyzed an asteroid spectral data set and an AVIRIS hyperspectral image, provided by the PI, with their alternative self-organizing methods (*e.g.*, Fyfe and Baddeley, 1995; MacDonald *et al.*, 1999), the results of which became part of the PhD dissertation of one of Fyfe's students (Donald MacDonald), and several C codes were given to the PI for incorporation to our neural core. Other algorithm developments include numerous details, added to existing capabilities. MacDonald *et al.*, (2002) is a joint publication.

Task 3: Visualization and human interaction

Significant effort was spent on the refinement of the Cluster Boundary Extractor (CBEXTR, now called REMAP), complete with sophisticated visualization. Sample capabilities are illustrated at the HYPEREYE demo web site, see Task 5. Live and mouse click indicators populate now the GUIs of ann-SOMxxx and REMAP modules. (xxx stands for variants of the SOM such as consc[ience] or BDH.) Decisions about visualization parameters are aided by statistics on weights, data density, fence (weight distance) values and others. Representations in both the SOM and reference images (in REMAP, for example) can be replaced by others on the fly. Independent information such as known class designation of labeled data points can be overlain an otherwise unlabeled SOM or reference image, at the click of the mouse. Numerous convenience and housekeeping features were added to these major ANN/SOM modules that considerably accelerate the semi-manual cluster identification described in the proposal.

Alternative cluster visualizations such as that by Cottrell and DeBodt (1996) were fully implemented, as planned, by current graduate student Kadim Tasdemir, who joined us in January, 2004. A number of additional schemes were also implemented, using various metrics and graphical representations. Tasdemir evaluated their relative merits in comparison to the widely used Ultsch ans Siemon (1990) scheme and its derivatives, in his PhD qualifying project.

In an attempt to try to *fully automate* the capture of clusters from a converged SOM (a task that has only partial solutions to date, worldwide), Jain implemented an algorithm that clusters the SOM weights. This algorithm is a modification (by Jain) of Vesanto and Alhoniemi (2000), and it seems to work very well for relatively simple data sets (A. Jain, M.S. Thesis, 2004). However, for more complex data, which are our target, the results are not satisfying. Kadim Tasdemir is taking over this research.

Task 4: Applying algorithms to real scientific data

Co-I Peter Smith provided calibrated, 8-band and 7-band Mars Pathfinder IMP SuperPan spectral images (from the left and right eye of IMP, respectively). Careful inspection of the SOM-clustered spectra revealed subtle calibration errors in the IMP reduction process in 2000, and provided an opportunity to improve the calibration. More IMP work was done later between Co-I Farrand and the PI. SOM clustering was performed on the S0184 left eye and S0184 right eye octants, which resulted in finding all spectral units known from previous research. Most interestingly, it resulted in finding tiny spatial occurrences of "black rock" mineralogies, spectrally consistent with mafic basalt, and moreover, identifying two subclasses of it with longer and shorter center absorbtions of the 1-μm pyroxene band, indicating possible ortho- and clynopyroxene mineralogies (Merényi, Farrand, and Tracadas, 2004; Farrand and Merényi, 2004). Subsequently, the S0184 octants and several others were subjected to supervised classification after careful labeling of training data based on the detailed clustering and on Farrand's domain knowledge and previous analyses. The resulting class maps are the first comprehensive spectral maps of the SuperPan data set. We are completing the classification of all octants under Farrand's Mars Data Analysis Program project. Graduate student Tasdemir participates in this work.

Co-I Brown provided a hyperspectral VIMS image of Jupiter from the Cassini fly-by in 2001. SOM analysis of it revealed "all the hot spots" (as Brown put it), and also brought out indications of a subtle instrumental effect. The clustered Jupiter image was submitted with our 2nd year report. Based on the success of that analysis, the PI and Brown plan to analyze Cassini VIMS images from the Saturn orbital tour, under the new AISRP grant NNG05GA94G, 11/1/04 - 10/31/07.

AVIRIS hyperspectral image cubes have been provided to the PI through collaborations. Perhaps the most interesting terrestrial analysis was that of three, 130 Mbyte images of the Colorado River Ecosystem, in which 21 species were mapped in contrast to 8 found by ENVI, the leading commercial hyperspectral package (Merényi *et al.*, 2000a, 2000b). Another analysis demonstrates, in addition to finding all known spectral classes, the discovery of spatially small, geologically interesting classes of surface material from a 140-Mbyte, 194-band spectral image of the Lunar Crater Volcanic Field (Merényi, 2000, Merényi and Villmann, 2002).

With Victor Baker (PI) and Larry Rudd, U Arizona, we investigated the mapping of clay minerals from AVIRIS hyperpsectral imagery, using a combination of SOM clustering and subsequent supervised neural net classification. This collaboration, under V. Baker's grant NAG9-9293 from the Solid Earth and Natural Hazards Program, aims to develop hazard maps for slope failure and debris flooding, a significant parameter of which is the type of clay contained in the soil. We successfully created detailed maps of the relevant mineralogies (Rudd and Merényi, 2003 and 2004), with assistance from graduate student Capt. Michael Mendenhall, who joined us in May, 2004. (Mendenhall is fully supported by the U.S. Air Force, therefore his contributions are at no cost to this and the next grant project.)

Task 5 Interactive demonstration of major interactive tools is provided at the HYPEREYE web site, http://www.ece.rice.edu/∼erzsebet/HYPEREYE, complete with online documentation, demo data sets and tutorial for easy reference to help novice users to quickly learn the fundamental SOM analysis "pipeline."

The HYPEREYE website demonstrates our main graphical user interface modules on toy datasets, illustrating the scientific use of each module, along with full online documentation. The online documentation for the HYPEREYE system now has a user documentation interface that identifies and orders module documentation by both functionality (using Figure 2 color codes) and name. We also added a whole new section of developer documentation (not posted at the HYPEREYE demo site), created in part by the Doxygen package, to aid in software development by students. A bug tracking facility was added to the website for internal use (thus does not appear on the demo site) to improve reporting quality and resolution time of bugs in code or documentation. The investigation of a java viewer for the demonstration modules revealed that one of the modules will not work under the viewer because of its legacy X libraries. Future re-coding of this (and other) modules to the QT library is planned and then the web java viewer will be considered for implementation. Since last year, users on any computing platform that can run an X server may try the actual tools we use every day. Up to now, the X-display method for running the demos has been enjoyed by viewers in Germany, Taiwan, Turkey, and the US.

Task 6, Augmentation of documentation and sample test data sets was accomplished as part of Tasks 1 and 5.

2.2 Publications and invited presentations

Most publications are posted at http://www.ece.rice.edu/∼erzsebet/ publications, html format.

Book chapter

Villmann, T. and **Merényi, E.** (2001), "Extensions and Modifications of SOM and its Applications to Remote Sensing Processing," In Recent Advances in Self-Organizing Neural Networks, Eds. U. Seiffert and L. Jain, Springer-Verlag. pp. 121–145.

Refereed journal and refereed conference proceedings

Merényi, E., Jain, A., Farrand, W.H. (2004), Applications of SOM magnification to data mining, WSEAS Trans. on Systems, 3(5): 2122 - 2128.

Jain, A., **Merényi, E.**, (2004), Forbidden Magnification? I., Proc. 12th European Symposium on Artificial Neural Networks, ESANN'2004, Bruges, Belgium, 28–30 April, 2004. pp. 51 - 56

Merényi, E., Jain, A., (2004), Forbidden Magnification? II., Proc. 12th European Symposium on Artificial Neural Networks, ESANN'2004, Bruges, Belgium, 28–30 April, 2004. pp. 57 - 62

Merényi, E., Farrand, W.H., Tracadas, P. (2004), Mapping Surface Materials on Mars From Mars Pathfinder Spectral Images With HYPEREYE, Proc. International Conference on Information Technology, ITCC04, April 5–7, 2004 Las Vegas, NV, USA, II:607 - 614.

Villmann, T.,**Merényi, E.**, Hammer, B. (2003), Neural Maps in Remote Sensing Image Analysis, Neural Networks, Special Issue on Neural Networks for Analysis of Complex Scientific Data, 16:(3–4):389-403.

Rudd, L., Merényi, (2003), The Use of AVIRIS Imagery To Assess Clay Mineralogy and Debris-Flow Potential In Cataract Canyon, Utah: a Preliminary Report, In Summaries of the Twelve Annual JPL Airborne Earth Science Workshop, Pasadena, CA, February, 2003. Ed. R.O.Green

Merényi, E., Villmann, T., (2002), Self-Organizing Neural Network Approaches For Hyperspectral Images, Proc. Int'l Conf. On Intelligent Computing and Information Systems, June 24-26, 2002, Cairo, Egypt, Eds. M. Tolba and A-B. Salem. pp. 33–41

MacDonald, D., Corchado, E., Fyfe, C., **Merényi, E.**, (2002), Maximum and Minimum Likelihood Hebbian Learning for Exploratory Projection Pursuit, Proc. Int'l Conf. on Artificial Neural Networks, Madrid, Spain, August 27–30, 2002.

Merényi, E., Farrand, W.H., Stevens, L.E., Melis, T.S., and Chhibber, K., (2000b), Mapping Colorado River Ecosystem Resources In Glen Canyon: Analysis of Hyperspectral Low-Altitude AVIRIS Imagery, Proc. ERIM, 14th Int'l Conference and Workshops on Applied Geologic Remote Sensing, 4–6 November, 2000, Las Vegas, Nevada. pp. 44 - 51

Merényi, Farrand, W.H., Stevens, L.E., Melis, T.S., and Chhibber, K., (2000a), Studying the Potential For Monitoring Colorado River Ecosystem Resources Below Glen Canyon DamUsing Low-Altitude AVIRIS Data, In Summaries of the Tenth Annual JPL Airborne Earth Science Workshop, Pasadena, CA, February 23–25, 2000. Vol. 1: AVIRIS Workshop, Ed. R.O.Green

Merényi, E. (2000), ""Precision Mining" of High-Dimensional Patterns with Self-Organizing Maps: Interpretation of Hyperspectral Images," In Quo Vadis Computational Intelligence: New Trends and Approaches in Computational Intelligence, Studies in Fuzziness and Soft Computing, Vol. 54, Peter Sincak, Jan Vascak, Eds. Physica-Verlag . pp. .

Villmann, T., Merényi, E., (2000), Extensions and Modifications of SOM and itsApplication in Satellite Remote Sensoring Processing, Proc. 2nd Int'l Computer Science Conventions Symposium on Neural Computation, NC'2000, May 23-26, 2000, Berlin, Germany..

Farison, J. B., Vanjara, U., Merényi, (2000), AVIRIS Image Compression With Orthogonal Projection and KL Transforms, Proc. IASTED Int'l Conference, SIGNAL AND IMAGE PROCESSING, Las Vegas, Nevada, Nov 19–23, 2000, Ed. M. H. Hamza, IASTED/ACTA Press, ISBN 0-88986-308-3. pp. 52-57

Farison, J.B., Vanjara, U., Merényi (2000), Feature extraction using the Orthogonal Projection Filter, Int'l Conf. on Imaging Science, Systems, and Technology (CISST'2000), Las Vegas, Nevada, June 26–29, 2000, I:223–229.

Abstracts

Rudd, L. and Merényi, E. (2004), The Use of AVIRIS Imagery to Assess Clay Mineralogy and Debris-Flow Potential in Cataract Canyon, Utah, Conf. of the Geological Society of America, Colorado Convention Center, Denver, Colorado, Nov 9, 2004 , (Abstract).

Farrand, W.F. and Merényi, E. (2004), Mapping soil and rock units in the MPF IMP SuperPan using a Kohonen Self-Organizing Map., Proc. 35th Lunar Planet. Sci. Conf. , (Extended abstract).

Thesis

Jain, A. (2004), *Issues Related to Data Mining with Self-Organizing Maps,* Master of Science Thesis, Rice University, Houston, Texas.

Invited Talks by PI

2003 "A Neural Map View of Hyperspectral Images", Seventeenth Annual Conference on Neural Information Processing Systems (NIPS 2003), Workshop on Hyperspectral Remote Sensing and Machine Learning, December 12, Whistler, B.C., Canada.

2003 "Computational Intelligence in the Service of Planetary Science", Lunar and Planetary Institute, Houston, TX, November 21, 2003.

2002 "Self-Organizing Neural Network Approaches For Hyperspectral Images", First Int'l Conference on Intelligent Computing and Information Systems, June 25, 2002, Cairo, Egypt.

2002 "Neural Networks and Other Things at Rice University", At Faculty of Computer & Information Sciences, Ain Shams University, Cairo, Egypt, June 27, 2002.

2001 "Analysis of High-Dimensional Patterns With Self-Organizing Neural Networks. Applications to Remote Sensing Hyperspectral Images", Rice University, Statistics Department seminar, November 19, 2001.

2000 "Mapping Colorado River Ecosystem Resources In Glen Canyon: Analysis of Hyperspectral Low-Altitude AVIRIS Imagery", ERIM, 14th Int'l Conference and Workshops on Applied Geologic Remote Sensing , Las Vegas, Nevada (4-6 November, 2000).

2000 ""Precision Mining" of High-Dimensional Patterns with Self-Organizing Maps: Interpretation of Hyperspectral Images", International Symposium on Computational Intelligence - ISCI 2000, Kosice, Slovakia, August 30 - September 1, 2000.

2000 "Pattern Recognition and Classification of High-Dimensional Signatures with Artificial Neural Networks: Self-Organizing Maps for Hyperspectral Image Exploitation", Electrical and Computer Engineering Department, Rice University, March 15, 2000.

2000 "Self-Organizing Maps for Rapid Identification of Planetary Resources: Neural Net tools for fast and effective information extraction from large (hyper)spectral images", NASA Headquarters, Washington, D.C., February 4, 2000.

Other presentations by PI and team members / collaborators

2004 "Applications of SOM magnification to data mining", 8th WSEAS Int'l Conf. on Systems, Circuits, Communications, Vouliagmeni, Athens, Greece, July 12 - 15, 2004 (**Merényi, E.**, Jain, A., Farrand, W.H.).

2004 "Forbidden Magnification? I. ", 12th European Symposium on Artificial Neural Networks,ESANN'2004, Bruges, Belgium, 28–30 April, 2004 (**Jain, A.**, Merényi).

2004 "Forbidden Magnification? II. ", 12th European Symposium on Artificial Neural Networks,ESANN'2004, Bruges, Belgium, 28–30 April, 2004 (**Merényi, E.**, Jain, A.).

2004 "Mapping Surface Materials on Mars From Mars Pathfinder Spectral Images With HYPEREYE", International Conference on Information Technology, ITCC04, April 5–7, 2004, Las Vegas, NV, USA (**Merényi, E.**, Farrand, W.H., Tracadas, P.).

2003 "HYPEREYE: looking at hyperspectral images through neural maps", NASA, OSSA, Applied Information Systems Research Program Annual PI Workshop, University of Pittsburgh, Pittsburgh, Oct 28 - 30, 2003 (**Merényi, E.**).

2003 "The Use of AVIRIS Imagery To Assess Clay Mineralogy and Debris-Flow Potential In Cataract Canyon, Utah: a Preliminary Report", Twelve Annual JPL Airborne Earth Science Workshop, Pasadena, CA, February, 2003 (**Rudd**, Merényi).

2002 ""Precision" Mining of Large Spectral Data Volumes For Rapid Identification of Planetary Resources.", NASA, OSSA, Applied Information Systems Research Program Annual PI Workshop, NASA Ames Research Center, Mountain View, CA, Oct 4 - 6, 2002 (**Merényi, E.**).

2002 "Maximum and Minimum Likelihood Hebbian Learning for Exploratory Projection Pursuit", Int'l Conf. on Artificial Neural Networks, ICANN'02, Madrid, Spain, August 27–30, 2002 (**MacDonald**, Corchado, Fyfe, Merényi).

2001 ""Precision" Mining of Large Spectral Data Volumes.", NASA, OSSA, Applied Information Systems Research Program Annual PI Workshop, Applied Physics Laboratories of JHU, Laurel, MD, Oct 16-18, 2001 (**Merényi, E.**).

2000 ""Precision" Mining of Large Spectral Data Volumes", NASA, OSSA, Applied Information Systems Research Program Annual PI Workshop, LASP, Boulder, CO, Oct 18-20, 2000 (**Merényi, E.**).

2.3 International conference program committees the PI served on

• Co-Chair, 8th WSEAS Int'l Conference on SYSTEMS, Special Session on Intelligent Information Systems (IIS), Vouliagmeni, Athens, Greece, July 12-15, 2004

• 12th European Symposium on Artificial Neural Networks, ESANN'2004, Bruges, Belgium, April 28-30, 2004

• Chair, Session on Learning, 12th European Symposium on Artificial Neural Networks, ESANN'04, Bruges, Belgium, April 28-30, 2004

• 11th European Symposium on Artificial Neural Networks, ESANN'2003, Bruges, Belgium, April 21-23, 2003

• First Int'l Conf. on Intelligent Computing and Information Systems, Cairo, June 24-26, 2002

• 10th European Symposium on Artificial Neural Networks, ESANN'2002, Bruges, Belgium, April 22-24, 2002

• Int'l Computer Science Conventions (ICSC) Symposia on Soft Computing and Intelligent Systems for Industry (SOCO'2001 and ISFI'2001), Paisley, Scotland, U.K., June 2001

• 9th European Symposium on Artificial Neural Networks, ESANN'2001, Bruges, Belgium, April 21-23, 2001

• Int'l Symposium on Computational Intelligence, Koice, Slovakia, Aug 29 - Sep 2, 2000

2.4 Proposals granted in this period

The following proposals, granted in this period, capitalize on work under AISRP support.

• "Precision Mining of Large Spectral data Volumes for Rapid Identification of Planetary Resources", from NASA OSSA Applied Information Systems Research Program. PI E. Merényi, 4/30/00-8/31/04. $580K. (this project)

• "Mapping and Analysis of Spectrally Unique Soils, Rocks and Rock Coatings on Mars at Local and Regional Scales Using Imager for Mars Pathfinder and Mars Odyssey THEMIS", PI W.H. Farrand, Space Science Institute, Boulder, CO. NASA MDAP, NAG5-13294, 4/1/03-3/31/06. $210K total budget, $25/26/6K/yr to Co-I Merényi.

• "Remote Sensing for Debris Flooding Hazard Assessment in Arid Regions", NASA ESE, Solid Earth and Natural Hazards Program. PI Prof. Victor Baker, U Arizona, $225K total budget, 3/30/00-2/28/03, $48K to Co-I Merényi.

• Fulbright Travel Award, to give invited lecture at the 1st Int'l Conf. on Intelligent Computing and Information Systems, June 25, 2002, Cairo, Egypt. Full cost supported.

• Brown Undergraduate Internships: Support for undergraduate students for academic semesters and/or summer, summer 2001, fall 2001, fall 2002, from Rice University, School of Engineering.

3 Future directions

Continuation of this work will go on under two AISRP grants: NNG05GA94G, 11/1/04 - 10/31/07 (PI E. Merényi), and NNG05GA63G, 10/15/04 - 10/14/07 (PI Eliot Young, SouthWest Research Institute, Boulder, CO).

Neural network / SOM algorithmic development will focus on researching the scope of controlled magnification (as described in Task 2); automation of cluster identification from the SOM; and a new topic, relevance learning. The latter topic draws on our collaborator Dr. Villmann's work, and aims to determine (by learning) the relative merits of contributions by the various data dimensions.

In addition to continued algorithmic and visualization support, HyperEye software development will complete the main GUI and update it to a "next generation GUI", which includes preparation for platform independence, for infusion of the technology into the community.

Real scientific data analysis projects will include classification of spectral data from the Mars Exploration Rovers (with Co-I Farrand), SOM clustering of hyperspectral VIMS images from the Cassini mission (with Co-I Brown), and neural net classification of spectra of icy solar system bodies (under Eliot Young's grant project, on which this PI is Co-I).

Independent of existing funded projects the PI has been exploring hardware implementation of large scale SOMs with a German group. Successful hardware processing would increase the speed by several magnitudes, providing extremely good conditions for efficient algorithm research and development, as well as for data analyses. The PI will be seeking funding opportunities for the hardware aspect.

4 References

Some of the PI's papers are downloadable at http://www.ece.rice.edu/∼erzsebet/publications.html

Bauer, H.U., Herrmann, M., Villmann, Th. (1997), Topology Preservation in Neural Maps of Real World Data, *Proc. 5th European Symposium on Artificial Neural Networks, ESANN'98, Bruges, Belgium, April 22–24, 1997,* pp 205–210.

Bauer, H.U., Der. R., Herrmann, M. (1996), Controlling the Magnification Factor of Self-Organizing Feature Maps, *Neural Computation,* 8:757–771.

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5 Appendix: Acronyms

ANN	Artificial Neural Network
AVIRIS	Airborne Visible and Infrared Imaging Spectrometer, of NASA, JPL
AVIRISLA	Low-Altitude AVIRIS
BDH	algorithm for SOM magnification control by Bauer, Der and Herrmann
BP	Back Propagation, an ANN paradigm
EO-1	Earth-Observing satellite, NASA
GSOM	Growing Self-Organizing Map, and ANN paradigm
HST	Hubble Space Telescope
HYDICE	Hyperspectral Digital Image Collection Experiment, Naval Research Lab
IMP	The Imager for Mars Pathfinder
Landsat TM	Landsat Thematic Mapper
Landsat MSS	Landsat Mulstispectral Scanner
LPL	Lunar and Planetary Laboratory; at University of Arizona
MGS	Mars Global Surveyor
ML	Maximum Likelihood classifier
PCA	Principal Components Analysis
SOM	Self-Organizing Map, a neural network paradigm
STIS	Space Telescope Imaging Spectrograph
UA	University of Arizona
VIMS	Visible-Infrared Mapping Spectrometer, Cassini mission